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A Reading-Writing Assignment Based on Popular Literature To Enhance Learning about Microbiology †

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In order to stimulate engagement in microbiology, a reading-writing assignment based on a narrative popular science book was created for a one-semester introductory microbiology course. In order to encourage critical thinking, students were required to formulate a question related to the book to research and report on. Active learning was supported by guidance and feedback at each stage of the assignment. The assignment components were graded according to a rubric based on the learning outcomes: reading comprehension, question formulation, literature research, synthesis, and written communication. Median scores for the assignment components indicated that students successfully demonstrated the learning outcomes. A question was included on the final examination, asking students to summarize their most important learning from the assignment. Qualitative analysis of the exam answers revealed a wide variety of lessons learned about the practical applications of microbiology. On average, students scored better on the assignment and the assignment-related exam question than on the final exam. There was no significant correlation between a student's performance on the final exam and their performance on either of the assignment-related assessments, suggesting that the assignment benefited students regardless of their exam-taking capability. According to surveys administered at the end of the introductory microbiology course and again when students were enrolled in a senior microbiology course, a strong majority of students found the reading-writing assignment to be engaging and informative. This assignment may be modified in various ways in order to suit the needs of other courses.

INTRODUCTION

Rationale

Helping students to see the "real-world" relevance of a topic motivates them to learn about that topic (1, 2). This can be achieved in various ways, such as using real-life examples in lecture or case studies for problem-based learning. Both of these methods employ narrative to a certain extent, which enhances learning (3, 4). Another approach that has been used successfully by educators in various disciplines is the incorporation of relevant narrative-based popular science literature (5–11).

About 10 years ago the author introduced an optional reading assignment into an undergraduate introductory microbiology course: the reading was a popular book about the eradication of smallpox (12). In response to positive student feedback over a few semesters, the reading assignment was made mandatory and a research-writing component was added. Because the author had noticed in previous years that many students struggle with writing, the assignment was designed to provide plenty of guidance and feedback at each of several stages. These stages involve active learning through reading, questioning, research, and writing. The assignment takes some classroom time, but is mostly completed as homework.

Intended audience

This activity was developed for students in an introductory undergraduate microbiology course for biology majors and science majors. It could be adapted for use in other undergraduate courses in science or general education.

Learning time

The introduction to the assignment takes approximately 30 minutes of class time at the start of the course.

Writing the rough draft in class takes 60 to 75 minutes. Progression through the entire assignment takes 8 to 11 weeks, depending on the deadlines for each component

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of the assignment. These can be adjusted to fit with other commitments within a course schedule.

Prerequisite student knowledge

In order to complete the assignment as presented, students should have successfully completed one or more courses in introductory cell biology and genetics. A two- to three-hour introduction to viruses given prior to the deadline for submission of the outline component of the assignment was found to be very beneficial. Students should also have taken an introductory composition or general education course that provides instruction in literature searches, reference citation, and avoiding plagiarism.

Learning objectives

In order to successfully complete this assignment, students will

1. read and comprehend a narrative book relevant to microbiology;
2. ask a question related to the book that may be answered through literature research;
3. find relevant information from reliable sources;
4. synthesize and explain information from references pertinent to their question;
5. write an original, concise report with correct citation of references;
6. learn something beyond the scope of the course syllabus about the practical importance of microbiology.

PROCEDURE

Materials

Ensure that students have access to the books chosen for this assignment and adequate access to current literature on microbiology and epidemiology.

Student instructions

At the start of the semester, students are given an in-class presentation that provides step-by-step guidance for completing the assignment, and the grading rubric (Appendices 2 and 3). They are given two weeks to choose a book from a selection provided by the course professor, read it, complete an open-book online quiz on the book's content, and submit two or more questions related to the book that they might research for a brief written report. Using feedback from the instructor at each stage, they refine one question, conduct literature research, submit an annotated bibliography, and submit an outline over the next several weeks according to a schedule posted on the course website. They bring the outline and annotated bibliography to an exam-style class session in order to draft a brief paper. Finally, they are expected to use instructor feedback on their draft to produce a final report outside of class and submit it within a specified time period. Detailed instructions are provided in Appendix 2.

Faculty instructions

Because this assignment runs over the better part of a semester, it is beneficial to get the students started on it right away. A semester timeline for the assignment is provided in Appendix 1.

Part of the first lecture session is devoted to explaining the structure and expectations of the assignment. The instructions and grading rubric (Appendices 2 and 3) are also posted on the course website, along with a link to the university's guidelines for referencing and avoiding plagiarism. Deadlines for each assignment component are posted in the course syllabus, along with the list of books that students can choose from. Richard Preston's *The Demon in the Freezer* (12) and *The Hot Zone* (13) were the inspiration for this assignment and were the only choices for several years (during which time learning data was collected). However, in the most recent academic year two other choices were added to the list: David Quammen's *Ebola: The Natural and Human History of a Deadly Virus* (14) and *The Chimp and the River* (15). These books have been chosen because they are quick reads that deal with infectious disease and the scientists who study them, and they are written in an engaging narrative style at a level that requires no prerequisite knowledge of microbiology.

The assignment is scaffolded and includes feedback at each stage, to promote students' learning and submission of original work. Providing students with feedback may be facilitated by the use of clearly labeled electronic assignment drop boxes on the course website.

The first step requires students to pass an open-book quiz based on the book that they read. Therefore, the course instructor needs to prepare a separate quiz for each of the books included in the selection list. The purpose of the quiz is not to determine whether a student has memorized every detail in the book, but rather to see if they are familiar with the main concepts and can quickly find details that they do not remember. The quiz may be administered in class or electronically. An example of each type of quiz is included in Appendix 4. While it takes a little time to set up the quiz electronically, doing so eliminates grading time at this step. Grading of written quizzes like the examples provided takes about three minutes per student.

The next stage requires each student to submit two or more questions related to the book but not answered by the book. Choosing an appropriate question to answer requires thoughtful input from the instructor, who must be familiar with each book in order to help each student to select and refine a question, or to come up with a different question altogether. On average, this takes the instructor about five

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minutes per student. Students who submit more than one suitable question are asked to indicate which one they will pursue. At this stage, the instructor may choose to ensure that no two students will be answering the same question, in order to encourage individual efforts. In the author's experience, there has been no shortage of unique questions, but it is difficult for many students to come up with a question that may be answered in a brief report based on scientific literature. It is important to make clear to students the length and scope of the report the instructor is expecting, and to help them frame their question to fit that scope. Sometimes even questions that seem very realistic yield little information, as is the case with the scientific process in general. It is beneficial to tell students that this is a possibility, and that they should consult with the instructor about adjusting their question if they find it to be unfruitful.

Once students have their approved questions, they conduct literature research and submit an annotated bibliography to the instructor. Students are instructed to include a hard copy or PDF of each of their references with the information that they used highlighted. This greatly facilitates grading, which should take about 10 minutes per student on average. At this stage, instructor feedback can reinforce proper citation, the selection of appropriate scientific references, and logical thinking about the question. At the next stage, the outline, the instructor may provide feedback on students' interpretation of the information in their sources as well as the originality of their wording and their organization of information. If the instructor has the students' annotated bibliographies on hand, grading at this stage should take 10 to 15 minutes per student.

At the penultimate stage, students write a rough draft of their report under supervision with only a hard copy of their outline for assistance. Although it requires time in class (60 to 75 minutes), this step reduces plagiarism dramatically. Instructor feedback should be restricted to comments regarding structure, logic, clarity, grammar, spelling, and reference citations that provide general guidance rather than specific suggestions. Feedback at this stage should take 10 to 15 minutes per paper. Students are required to return their rough drafts to the instructor for reference.

After using instructor feedback to compose their final reports on their own time, students use an electronic plagiarism checker to ensure that their work is original prior to making their final submission. Grading at this stage should average about 10 minutes per paper, because instructors will have access to the rough drafts and their previous comments.

The final report and the preceding submissions are graded according to the rubric that the students are given at the beginning of the semester (Appendix 2).

Suggestions for determining student learning

In order to encourage students to take advantage of instructor feedback, the grading rubric for the assignment (Appendix 3A) was designed to reward effort throughout the early stages, and to be quite stringent regarding the final product.

In order to ensure that students have actually read and understood their chosen book (Learning Objective 1; LO1), they are required to pass a quiz before they can proceed with the assignment. For the first few years that the author employed this assignment, a written open-book quiz was done in class under exam conditions. This has the advantage of ensuring that students do not cheat, but it adds to the grading load. In recent years, the written quizzes have been replaced by timed online multiple-choice quizzes (50 minutes, no repeat attempts). An example of each type of quiz is provided in Appendix 4. In order to proceed with the rest of the assignment students must score at least 50% on the quiz, but a higher score (60–70%) is required to earn the allotted mark for this component of the assignment.

The second learning objective, which requires students to ask a question related to the book that may be answered through literature research, requires careful reading, critical thinking, and a scientific approach to questioning. A sincere effort is all that is required to earn a mark on this component of the assignment. However, each student must come up with an approved question before they are allowed to continue the assignment. A surprising number of students have initially submitted questions that demonstrate curiosity about the story line but are very unlikely to be answered by scientific research. These students have been given another chance to come up with something more scientific. Many students have asked questions that are scientifically sound, but very general; they were asked to narrow their questions. Over the years a few students have asked thoughtful questions that are tangential to the central theme of the book but have been inspired by something in it. The author has allowed students to pursue their interest, as long as it was related to microbiology and/or infectious disease epidemiology. A few students have been curious about what a particular researcher-character has done since the time period of the story; these types of questions have generally yielded interesting information.

The assessments of students' ability to find information from reliable sources (LO3), to synthesize and explain information from those sources (LO4), and to write an original, concise report with correct reference citations (LO5) are divided into formative and summative stages. Sequential formative assessments of the annotated bibliography, the outline, and then the rough draft provide constructive feedback that the student can use to improve their work. For the annotated bibliography and the outline, a mark is given as long as the student makes a sincere effort and eventually meets the requirement, and success is required before the student can proceed to the next step. For the instructor's sake, it is useful to put a limit on how many resubmissions are permitted; one may be sufficient. Feedback on the rough draft should focus on the demonstration of the major learning outcomes, with only general comments on grammar,

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spelling, and formatting of references. These can be graded upon receipt of the final report.

Grading of the final report provides the summative assessment of students' ability to find information from reliable information sources (LO3), to synthesize and explain information from those sources (LO4), and to write an original, concise report with correct reference citations (LO5). An exemplar of a final report is included in Appendix 2. As indicated by the rubric, the final report is worth 75% of the reading-writing assignment, and is graded quite stringently. The high expectations at this stage are justified by the amount of guidance and feedback that students have received in the earlier foundational stages.

The inclusion of the columns "Fail Report" and "Penalty" in the rubric is meant to provide transparency and to encourage students to behave responsibly in following directions, meeting deadlines, and resisting academic dishonesty. Discretion is used in providing second chances when a student presents a valid reason for lateness.

As a final assessment of independent learning from this assignment (LO6), a question about it is included on the final exam. Students are warned about this no later than the middle of the semester, and are reminded again at the end of the semester. Because students focus on different topics, the question is open-ended, asking them to write about the most important thing they learned from the assignment. Marks are awarded depending on the depth and accuracy of the answer (see the rubric in Appendix 5). The weighting of this question has varied between two and three percent of the final exam.

Sample data

While there has been some overlap in choice of topics over different semesters, there has been a great deal of variety, as was expected from such an open-ended assignment. Table 1 lists some examples of assignment topics from students enrolled in the introductory microbiology course from fall 2012 to winter 2015.

TABLE 1.
Examples of report topics.

Assignment topics
A summary of Dr. Lisa E. Hensley's work
Comparing degrees of pathogenicity of Ebola Reston between humans and non-human primates
The emergency response plan for a smallpox outbreak
Bacillus anthracis and *Bacillus thuringiensis*: A comparison
How does a virus become a trans-species virus?
Comparison between Ebola Reston and Ebola Zaire
Why is inhalation anthrax more fatal than cutaneous anthrax?
Consequences of habitat fragmentation and urbanization: Transmittance of Nipah virus
Research suggests that the origin of filoviruses is within the genomes of mammalian organisms
A brief comparison between HIV and smallpox
What characteristics of the big genome of smallpox make it able to fight the immune system in humans?
Differences between Variola major and minor genomes that are responsible for differences in pathogenicity
Vaccine production
Anthrax treatment
Evolution of filoviruses
Genetic mechanisms of Variola pathogenicity
How viruses jump between species
Potential vaccines for Ebola

Safety issues

There are no safety issues associated with this activity.

DISCUSSION

Field testing

Field testing involved the collection of coursework data and surveys from students in the author's two microbiology courses. The focus of the introductory microbiology course is on the basic biology of microbes, while the subsequent course covers the immune system, infectious diseases, mechanisms of pathogen transmission and pathogenicity, and epidemiology. Study protocols were approved by the Mount Royal University Human Research Ethics Board, and ensured informed consent, confidentiality, and anonymity of surveys and consent forms. Both survey and assignment data were collected over six semesters (fall 2012 to fall 2015; n = 180). The majority of the students were biology majors and general science majors in their second or third year of undergraduate study.

From the first semester that the reading-writing assignment was incorporated into the course, the response from the students has been overwhelmingly positive. Data from Likert-style surveys was collected from 180 introductory microbiology students over six semesters. A strong majority of students enjoyed reading the book, and perceived that the assignment was useful for learning about microbiology and the work of scientists (Fig. 1). The extent to which students reported a perception of learning from the assignment was correlated with their enjoyment of reading the book (p = 0.01, gamma test for collapsed ordinal non-parametric data).

Students' positive perceptions lasted well past the end of the introductory microbiology course, as shown by Likert-style surveys completed by students in the subsequent

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course, which is taken four months to two years after the introductory course has been completed. The senior group of students, mostly in their third or fourth year of study, were surveyed over three fall semesters (2014, 2015, 2017; *n* = 60). The response from the senior group to a question about the learning value of the reading-writing assignment done in the previous course was as least as positive as that obtained from students in the introductory course (Fig. 2). Written comments on the surveys showed a trend consistent with the Likert question results: of 58 comments, 66% were positive, 23% were quite positive with suggestions for improvement, and 11% were negative (see Appendix 7). Some examples of positive comments from students are provided below.

> *It was interesting because here is a book that you do not need any mibi background to read but its so phenomenal that it makes you want to understand the concepts (mibi) behind it.*
>
> *Yes, I really liked it because the book made the concepts very interesting. Then since I was interested I started to want to ask questions which was perfect for the writing assignment. It was great practice for other courses as well.*
>
> *I think the writing assignment made me read the book and remember it. I'm not much of a reader but when you're being tested on it, it motivates you to remember the stories involving microbiology. It is nice to have conversational pieces of a course as interesting as MIBI!*
>
> *Yes, I loved the novel and the writing assignment. It was a pleasure to work on/complete and definitely furthered my knowledge on Ebola. I can't think of any way it could have been improved. I also enjoyed the feedback system of submitting a rough draft initially - this helped me achieve a better grade.*

It is clear from the surveys that the majority of students found the reading-writing assignment to be useful and engaging, and that this perception lasted well past the semester during which they had taken the introductory microbiology course.

Evidence of student learning

Data regarding the attainment of learning objectives were gathered from introductory microbiology students (winter 2013 and fall 2013; *n* = 43). Evidence regarding learning objectives LO1 to LO5 was obtained from scores on the various components of the reading-writing assignment (Fig. 3). The requirement for a minimum level of competency on the quiz (reading comprehension), question selection, and reference selection yielded high average scores for these components. The average scores for explaining concepts

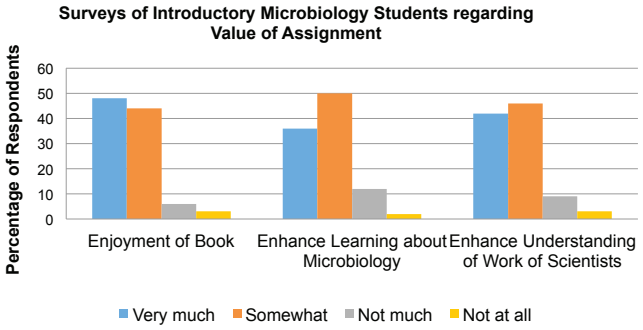

FIGURE 1. Surveys of introductory microbiology students regarding value of assignment. The majority of students surveyed enjoyed the book and thought that it enhanced their understanding about microbiology and the work of scientists.

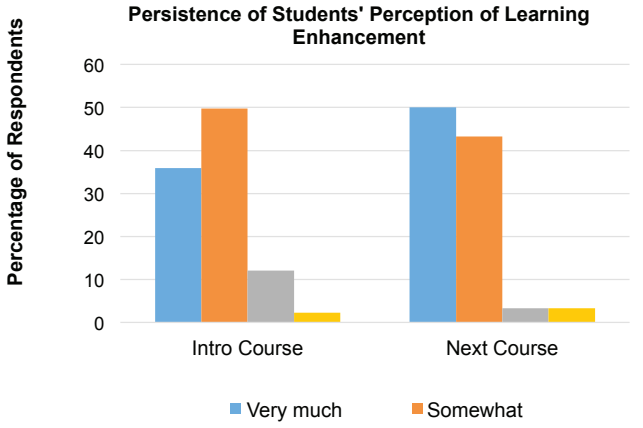

FIGURE 2. Persistence of students' perception of learning enhancement. When students in a later course were surveyed about the assignment that they had done in introductory microbiology, the majority indicated that they thought it had enhanced their learning about microbiology.

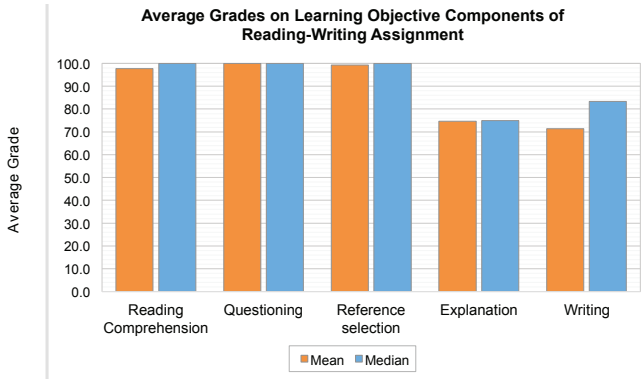

FIGURE 3. Average grades on learning objective components of reading-writing assignment. The requirement for a minimum level of competency on the quiz (reading comprehension), question selection, and reference selection yielded high average scores for these components. The average scores for explaining concepts and writing the final report were above 70%. Median values were equal to or higher than mean values, indicating that few students scored less than 70% on any aspect of the assignment.

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and writing the final report were above 70%. Median values were equal to or higher than mean values, indicating that few students scored less than 70% on any aspect of the assignment. The data indicate that a large majority of the students met the learning objectives for the assignment.

Students' answers to an open-ended question on the final exam were used to assess the extent to which they had learned something beyond the scope of the course syllabus about the practical importance of microbiology (LO6). Exam answer themes (Table 2) show substantial diversity, and generally indicate learning about practical applications of microbiology and the work of scientists in microbiology-related fields. Although the exam question did not probe for affective outcomes, some students' answers directly indicated their emotional engagement with the assignment. Sample exam answers and their associated scores are included in Appendix 6. An example of an answer worth full marks is shown below.

> *The book report really tied the concepts learned from a variety of courses to me. In class when things are learnt, they are learnt in definitions and lists. Reading the Hot Zone and doing the book report really put things into perspective for the applicableness of this course and viruses. I was able to combine viral entry and lysis of leukocytes from the book report with concepts that I was learning in pathophysiology, such as leukocyte rolling and liquefactive necrosis. I'm really glad that I chose to do these two courses at the same time for that reason. The Hot Zone also brought to life how host specific viruses are. Although the virus can jump between bats, monkeys and humans, I found it interesting that not one person involved in the Reston incident died of Ebola. The book also makes you have respect for viruses, because even though they are so small and less complex than other organisms, they can also be extremely lethal. Ebola is considered a large virus, but even then, it is small compared to typical bacteria and red blood cells. Ebola can still have widespread effects and is extremely lethal very quickly.*

TABLE 2.
Thematic analysis of answers to exam question.

Themes	# Mentions
Containment, vaccines, eradication *	52
Different strains, mutation	49
Pathogenicity and symptoms *	46
Routes of transmission, spread of disease, source of outbreak *	37
Bioweapons *	25
Level 4 Biosafety procedures *	19
Institutions, politics, and ethics *	16
Viral morphology	5
Careers in microbiology *	4
Inaccuracy of public information *	3
Reading skills, writing skills	3

* Not explicitly taught in class

Figure 4 compares the students' mean scores on the assignment, the assignment-related exam question, and the final exam in total. As a group, students had greater success in the assignment-related aspects of the course compared to the final exam. While the final-exam grade distribution resembled a normal curve, the grade distributions for the assignment-related assessments were skewed toward the higher numbers (data not shown). An analysis of individual students' grades revealed a lack of correlation between students' scores on the final exam and their scores on the assignment-related assessments (less than 0.5 using Pearson's or Spearman's correlation tests for matched samples; Figure 5). These data suggest that success on the assignment-related aspects of the course was possible for different types of students, and was not dependent on exam-taking ability. This conclusion is consistent with research showing that engagement, guidance, feedback, and active learning strategies promote student success (2).

Possible modifications

The reading-writing assignment described in this article may be modified in numerous ways. The author has tried placing students in groups to come up with questions and/or to discuss the answers they find, and plans to work on improvements to those processes. In response to comments from some students who were taking the

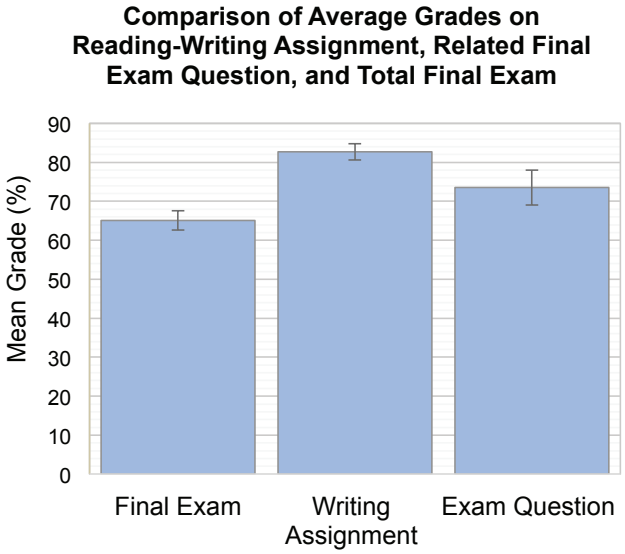

FIGURE 4. Comparison of average grades on reading-writing assignment, related final exam question, and total final exam. The mean grades for the assignment-related components of the course were higher than the mean final exam grade.

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course quite late in their program, a less-guided option of the assignment was offered, with a slightly modified grading rubric (see Appendix 3B). If class time is very limited, the instructor could forego the in-class written draft altogether. Because this step greatly encourages students to use their own words, additional checks for plagiarism may be desirable.

The choice of book(s) read for the assignment may be modified or expanded. In the field of microbiology there is a wide choice of appropriate narratives. All data collected for this article were based on the use of Richard Preston's books *The Demon in the Freezer* and *The Hot Zone*. However, the author has more currently used David Quammen's *Ebola: The Natural and Human History of a Deadly Virus* and *The Chimp and the River.* In addition to journalistic narratives, fictional narratives might be considered, if they are based in scientific reality.

Although the author did not include any discipline-specific conceptual learning outcomes as objectives of the reading-writing assignment, these could be incorporated quite easily. For microbiology courses, the books mentioned above could be used to promote learning about the characteristics, evolution, and pathogenicity of specific viruses; techniques used to study viruses and infectious disease outbreaks; and methods for preventing and controlling infectious disease outbreaks, to name a few.

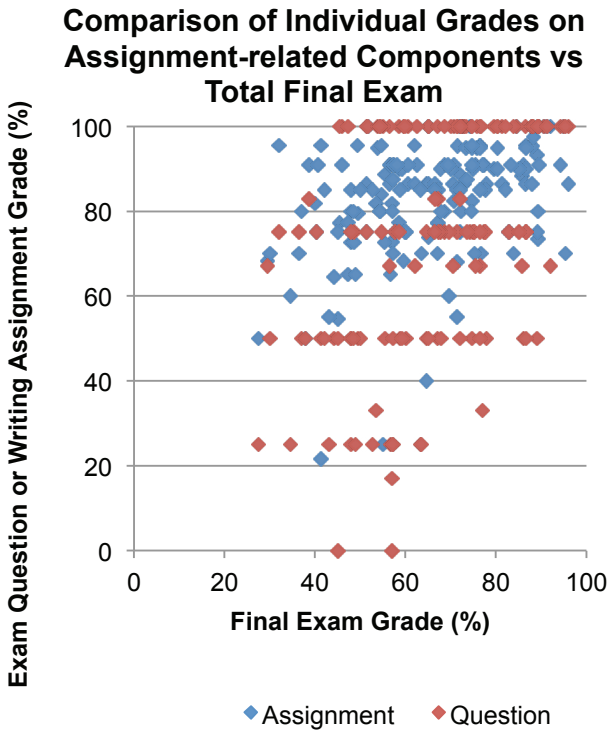

FIGURE 5. Comparison of individual student grades on assignment-related components versus total final exam. A comparison of individual students' grades for course components (confidence intervals) showed a lack of correlation among matched samples with a value of less than 0.5 using both Pearson's and Spearman's correlation tests.

Finally, this assignment may be adapted for use in other scientific disciplines for which appropriate popular narratives exist (5–7, 9–11). For example, the appropriate choice of book(s) could provide students with the opportunity to become immersed in the world of chemistry, physics, cell biology, or neuroscience (as just a few examples), formulate questions, and research conceptual or practical aspects of these disciplines.

SUPPLEMENTAL MATERIALS

Appendix 1: Semester timeline for reading-writing assignment
Appendix 2: Student instructions
Appendix 3: Assignment grading rubrics
Appendix 4: Examples of quizzes
Appendix 5: Rubric for grading answers to the question on the final exam
Appendix 6: Examples of exam answers
Appendix 7: Student comments

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One potential conflict of interest was identified in the proposal approved by the Mount Royal University Human Research Ethics Board. This was the dual role of the researcher as the professor of the students being studied. This potential conflict of interest was mitigated by keeping the surveys anonymous, by the collection of surveys and letters of consent by colleagues not involved with the study, and by offering anonymous withdrawal until after course grades were finalized. This was conveyed to student participants in writing prior to collection of consent forms.

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